Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Amendment of Part 73 and 74 of	)	
the Commission's Rules to permit	)	MM Docket No. 94-130
unattended operation of broadcast	)	
stations and to update broadcast	)	
station transmitter control and	)	
monitoring requirements.	)	

COMMENTS OF
BROADCAST ELECTRONICS, INC.

Broadcast Electronics, Inc. (herein "BE") hereby submits the following comments in response to the Notice of Proposed Rulemaking in the above referenced proceeding. Broadcast Electronics is one of the three largest manufacturers of radio broadcasting equipment in the United States. Now in it's 36th year, BE designs and manufactures a broad line of radio products including audio cartridge machines, digital audio storage products, audio mixing consoles, digital program control systems, AM stereo transmitters, FM Stereo transmitters and transmitter control systems. With more than 4,000 FM exciters and 1,500 FM transmitters in service, the company is one of world's leading producers of radio transmitting equipment.

I. Introduction

BE strongly endorses the Commission's initiative to waive the requirement that a broadcast station must have a licensed radio operator in charge of the transmitter during all periods of broadcast operation. We also agree with the Commission's efforts to update various transmitter control requirements to make them more relevant to unattended operation and to be responsive to commonly asked questions concerning their interpretation. We further believe that the current state of technology will allow these changes to be implemented at minimal cost to the broadcaster without endangering the quality or quantity of broadcast service available to the public. We urge the Commission to allow licensees and manufacturers maximum flexibility in utilizing these technical advantages by not adopting arbitrary or restrictive standards limiting or controlling the specific way that facilities are designed, built and operated.

II. Suitability of Current Transmitters for Unattended Operation

We agree with the Commission's basic premise that *"the requirement for a licensed duty operator and the costs and burdens imposed by such requirement no longer appear to be necessary or appropriate in light of the many improvements which have been made in the stability, reliability and automatic control of transmission systems."* Based on our experience as a manufacturer we also support the staff's observation and conclusion that *"knowledge obtained from inspecting stations...suggests that... it is rare that the duty operator is contacted (by the ATS monitoring equipment) concerning equipment malfunction. It thus appears that modern monitoring and control equipment has rendered the need for the duty operator largely superfluous...and this level of automation should be readily available to most broadcasters."* We also feel that this practical observation strongly supports our belief that AM and FM broadcast transmitters as currently being designed and built by our company and numerous other vendors are well suited for prolonged unattended operation without any modification or additional external monitoring equipment. We base this conclusion on our knowledge of transmitter design and years of daily experience analyzing transmitter failures while helping customers deal with maintenance and repair of their transmission facilities.

Modern transmitters are a far cry from the cranky, maintenance intensive beasts that were common when the current rules were adopted. At that time the cautions built into the present rules were appropriate protections to insure the *"the technical integrity of emitted signals"*. That situation has changed. We believe that the protection circuits included in contemporary transmitters to prevent damage to the transmitter in case of malfunction combined with the contemporary audio processing equipment used by most licensees afford more than adequate protection against harmful interference to other broadcasters and that the utilization of such equipment should be the only requirement imposed on the licensees. In support of this position, we will examine the possible causes of harmful interference and demonstrate how contemporary transmitter design protects against each.

The first possibility is off-frequency operation. When the current operator rules were established the frequency of broadcast transmitters was determined by a crystal. This was simply a piece of tuned rock mounted in a holder. A small electric current caused the rock to vibrate and these vibrations determined the operating frequency of the transmitter. Needless to say, many factors could influence this "rock" and human operators had to be alert for changes that would allow the transmitter frequency to drift beyond legal limits.

This is not the case for contemporary transmitters. The operating frequency of these units is determined by highly stable circuits employing phase lock loop or digital counting technology in self-correcting Automatic Frequency Control (AFC) circuits as the frequency standard. These circuits "lock" onto the operating frequency and then apply small, constant, incremental corrections to stay on frequency. A loss of "frequency lock" is easily detected by monitoring critical parameters in this circuit. As noted in

Appendix A, a circuit sensing this "loss of lock" is used to shut off the high power amplifier stages of most existing transmitters to prevent the damage to output devices and filters that would be caused by trying to pass significant amounts of off-frequency energy. In acting to protect the transmitter these circuits also protect other broadcasters from interference. Our experience over many years indicates that these circuits are highly reliable and act most dependably on the rare occasion when a frequency error occurs.

The second cause of harmful interference is over power operation. This situation is addressed by two features common in modern transmitters; automatic power controllers and overload protection circuits for the final amplifier.

The output power delivered by AM and FM transmitters is affected by many factors. The most common variables are changes in the line voltage on the incoming power line and changes in the impedance of the antenna system. The ambient temperature in the transmitter room can also affect this parameter but to such a small extent that it can largely be ignored. To assist broadcasters in dealing with these influences, most contemporary transmitters offer an automatic output power controller either as an integral part of the transmitter or as an optional accessory that is installed during transmitter construction. (See Appendix B for examples.) In either case, these circuits monitor the output power of the transmitter on a continuous basis and make corrections to hold it within limits set during the initial installation. Once again our experience with these circuits has been very good. They consistently perform correctly and rarely require repair.

A second set of circuits backup the action of the Automatic Power Controllers in transmitters so equipped and offer primary protection in those without the option. These are the current and voltage overloads on the final amplifier. Once again, the primary purpose of these circuits is to prevent damage to the transmitter, but their secondary effect is protection of the spectrum. These circuits are routinely included in every transmitter sold in the United State. The diagrams in Appendix C show typical examples of this feature in a variety of tube and solid state transmitters.

These circuits protect the output devices and power supply in transmitters by constantly monitoring the current and voltage being consumed by the Radio Frequency (RF) amplifiers in the transmitter. If the amplifiers draw too much current or the voltage being produced by the power supply reaches an unsafe level, the overload circuits activate and the transmitter shuts down. Since these parameters directly reflect the amount of power being produced by the transmitter, shutting the transmitter down when they reach preset limits will prevent the transmitter from emitting too much power and causing interference. Most manufacturers currently calibrate the trip point for these overload circuits to protect the components in the transmitter but there is no reason they could not be set to limit the output power of the transmitter to levels that would not cause interference. Once again our experience has shown that these overload circuits are extremely reliable.

The final likely source of harmful interference is excessive deviation or over-modulation. This condition would occur when the audio level applied to transmitter is excessive. Once again this concern is more than adequately answered by contemporary equipment and practices.

When the present operator rules were adopted, station engineers controlled transmitter modulation by sitting at a console and constantly "riding gain" (adjusting the audio level being fed to the transmitter) to make certain that it remained at a high enough level for the audience to easily hear the material being broadcast without reaching a level that would either cause the transmitter to deviate beyond its allotted frequency band or overload and shut down. This was a difficult challenge due to the wide dynamic range of most program material. Engineers immediately began to seek a better solution. This quest led to the development of an increasingly sophisticated series of "audio processors" that offer a wide range of sophisticated control options.

As indicated by the examples included in Appendix D these options range from simple diode based peak limiters that prevent overmodulation by chopping off any audio input voltage variations that would cause the transmitter to exceed the desired modulation limits to sophisticated, multi-function devices that analyze and tailor the spectral content, level and density of the audio signal before it fed to the transmitter. While the variety of these devices is fascinating and their design and marketing are extremely creative endeavors they share one critical characteristic in common. They are universally able to carefully control the final level of audio drive to the transmitter. This means that instances of harmful interference due to excessive modulation can be easily prevented.

In considering the appropriateness of allowing licensees to use these devices as the sole safeguard against excessive modulation, the Commission may ask two questions. The first might be "How many stations currently use such devices?" while the second might be "Do stations use other methods that might be more appropriate?" Both of these questions can be answered in a single observation. As our field personnel travel to stations through out the US and discuss technical operations with thousands of others by phone they find some form of audio processing device in use at almost every station. The reason for this widespread adoption is simple. Competition. The audio signal is a radio broadcasters sole product. In order to maximize his revenue or audience satisfaction every broadcaster wants his product to sound as good as his competition. (And be aware that this "competition" now includes items such as audio cassettes, CD's and cable television music channels). To meet this challenge almost every broadcaster has been forced to adopt some type of audio processing equipment. They are using the tools already to be competitive. The fact that the use of such devices enhance spectrum preservation is a welcome side effect.

In conclusion we urge the Commission to recognize the reality that as presently equipped most radio stations are already suited for unattended operation. Any new rules or regulations requiring additional equipment to qualify for unattended operation are unnecessary and would impose an inappropriate burden on licensees.

III. Comments on the Need for ATS Systems for Unattended Operation

In the Notice initiating this inquiry the Commission asked specifically if unattended operation should be permitted only when a station is equipped with an Automated Transmitter System (ATS). Given our experience with the transmitters currently being produced as detailed in the previous section of these comments we do not feel such a requirement is necessary. The transmitters are fully capable of sensing conditions that could lead to harmful interference and shutting themselves off without any additional external equipment. To arbitrarily require any particular type of additional equipment would increase the cost to licensees without affording any benefit to the public or other broadcasters. We urge the Commission not to impose such a requirement.

If the Commission fails to agree with our conclusions and decides to require an ATS system for stations operating unattended we offer a suggestion for this implementation. As noted in the NPRM the critical question in unattended operation is guarding against harmful interference to other broadcasters. In specifying any ATS requirement we would request that the Commission restrict their actions to identifying parameters that should be monitored and controlled avoiding any attempt to specify either the structure of the monitor and control equipment or the operating characteristics for such equipment.

This suggestion is consistent with the Commissions stated policy of leaving the implementation of its rules to those governed by them but we feel it is important to restate what may seem obvious. There are many valid approaches to meeting a technical need. In our experience the best technology implementations occur when an absolute minimum of restrictions are placed on methodology at the beginning of the design process. This is especially true when developing a new approach to a mature technology such as broadcast transmission. Broadcasters will receive maximum benefit from unattended operation only if equipment suppliers have the freedom to support ATS requirements by capturing capabilities in existing equipment to support the new requirements rather than requiring the arbitrary development of new devices just to meet an arbitrary configuration profile. There are ample existing devices to meet the requirements for unattended operation. Please allow those with the greatest knowledge of the technology determine the best way to implement compliance with any proposed standard.

IV. Special Considerations for Unattended Operation of Directional AM Stations

The Commission is correct to identify directional AM as a transmission technology that may require special consideration for unattended operation. Directional AM antenna systems contain many active elements that can effect the amount of signal transmitted in a given direction. Many systems also change operating modes several times during a 24 hour period thereby dramatically increasing the probability that a switching malfunction may create a situation where signal is transmitted in the wrong direction causing interference to other licensees.

Often faults in the antenna are reflected back to the transmitter causing the built-in overload circuits discussed in Section II to act, reducing the power output or shutting off the transmitter entirely. In fact this situation is the most common cause of "OFF-AIR" situations reported to our technical service division by AM broadcasters. Unfortunately it is difficult to predict which failures will upset the common point impedance sufficiently to cause a shut down. Since this action cannot be guaranteed it is not a satisfactory safeguard against destructive interference.

Fortunately a solution is readily available to broadcasters. A number of "smart" remote control systems as well as dedicated site controllers are already available from Broadcast Electronics and other vendors that are fully capable of continuously monitoring the complex operating parameters of a directional AM antenna system and shutting the transmitter off if a parameter exceeds the tolerances allowed by Commission regulations. Examples of several of these systems are included in Appendix E.

These "smart" devices also include a real time clock and programmable controllers. This allows the licensee to automate the changing of transmitter power levels and antenna system operating modes that may be required several times during the broadcast day. The monitoring functions mentioned in the previous paragraph are also updated as the operating parameters are altered so that appropriate safeguards remain in place for each mode of operation.

Given the ready availability of these sophisticated controllers we would urge the Commission to allow directional AM stations to operate unattended. We would further urge the Commission not to set any specific control requirements for these operations. Broadcasters have a wide choice of technologies available to automate the operation of AM directional antenna systems. As responsible licensees they should be allowed the freedom to equip their businesses as they see fit. The Commission should be prepared to accept whatever systems a particular licensee chooses to use as long as the facility operates within the Commission's technical standards. We do not believe there is any class of facility or normal operating circumstance that does not lend itself to unattended operation without human verification.

V. Tower Lighting and Unattended Operation

We agree with the Commission's concern about the appropriate monitoring of tower lighting but urge the Commission not to over emphasize it's importance in these proceedings. The current tower light monitoring requirements have been in place for a number of years. Inspite of the relatively casual inspection requirement (once a night) and the fact that field inspectors have encountered numerous malfunctioning tower light systems during station inspections a search of the public record fails to identify an instance where a broadcast tower light failure has been the cause of an aeronautical accident. Based on this observation we believe that the Commission might justifiably act to eliminate the tower light monitoring requirements from the rules.

If the Commission is unwilling to eliminate the monitoring requirements, we would urge them to allow licensees to use one of a number of fully automated tower light monitoring systems currently available during periods of unattended operation. Examples of several systems are included in Appendix F. These systems have proven to be highly reliable and offer a level of compliance that far exceeds the present requirement.

We further feel that licensees should be allowed to comply with the tower light monitoring requirement manually even if they operate unattended. It is perfectly reasonable to continue to allow an employee of the station to make the once-a-night tower light inspection even if they are not actively operating the station at that time. This flexibility would meet the safety concerns of the public without creating an undue hardship for broadcasters.

VI. EBS/EAS and Unattended Operation

The structure of the new Emergency Alert System is well suited to automatic implementation. It will be relatively easy for a licensee to fully comply with their EAS responsibilities without human intervention. Equipment currently exists that will support this method of operation. BE and a number of other vendors are developing additional implementation options on an ongoing basis.

The Commission has an excellent opportunity to encourage the rapid implementation of the EAS. We believe that progressive broadcasters who take the lead in implementing the new system should be allowed to begin unattended operation as soon as their new EAS equipment is installed. This will reward those who risk the time and expense of "debugging" the new alert system and offer a strong incentive for licensees not to postpone their system upgrades to the last minute. This will benefit both the licensees and the public at no risk to either.

VII. The "Contact Database" Requirement

We endorse the desirability of maintaining a single, complete, up-to-date contact database of every licensed broadcast installation in the United States. Such a resource would be invaluable to regulators and broadcasters alike. We urge the Commission to commit the necessary staff resources to begin implementing this program as soon as possible.

VIII. Time Limits for Out of Tolerance Operation

We generally agree with the observations and proposals included in the Notice concerning the procedures to be followed when an out-of-tolerance condition occurs at a broadcast station. However our extensive field experience compels us to offer one suggestion. There have been numerous instances when the repair or readjustment of AM Directional Antenna Systems or multi-station FM Master Antenna systems have required the operation of one or more stations in a mode that exceeded the tolerance limits of its license in one or more ways for periods longer than the proposed three minutes. Fortunately the current regulations permit such operation in the period between midnight local time and local sunrise. We believe that this experimental period could become even more important in an age of unattended operation. It is quite likely that traveling teams of maintenance engineers may visit a site only occasionally and need to observe its operation in several different modes to verify its correct operation and calibrate the monitor and control circuits for the transmitter and antenna system without having to spend several days at the site. Preserving the experimental period would answer this need and should be part of the present proceeding.

IX. Permissible Connection Methods for Remote Control

In the Notice the Commission notes "methods that depend upon non-dedicated control circuits such as "dial up" facilities would require that the transmitter remote control system include an alternate method of quickly acquiring on-off control." We do not agree with this requirement. In designing and testing our own "dial up" facilities controller we did not discover any evidence that would support the need for an alternative "full time access" method for transmitter ON/OFF control. Over several years of experimentation and in discussion with numerous broadcasters we found very few instances where operators were unable to establish contact with transmitter sites quickly, consistently and reliably. The inclusion of a "full-time ON/OFF" connection requirement would be an unnecessary burden to broadcasters that cannot be justified by our experiences.

X. Conclusion

We strongly encourage the Commission to allow unattended operation of broadcast facilities. We believe that a vast majority of broadcast stations can be safely operated unattended with their existing equipment. There appears to be no need for special ATS or monitoring equipment. If the Commission does not agree their actions should only detail the parameters to be monitored during unattended operation. They should not address the specific manner that licensees use to accommodate the required monitoring and control standards.

Respectfully submitted,

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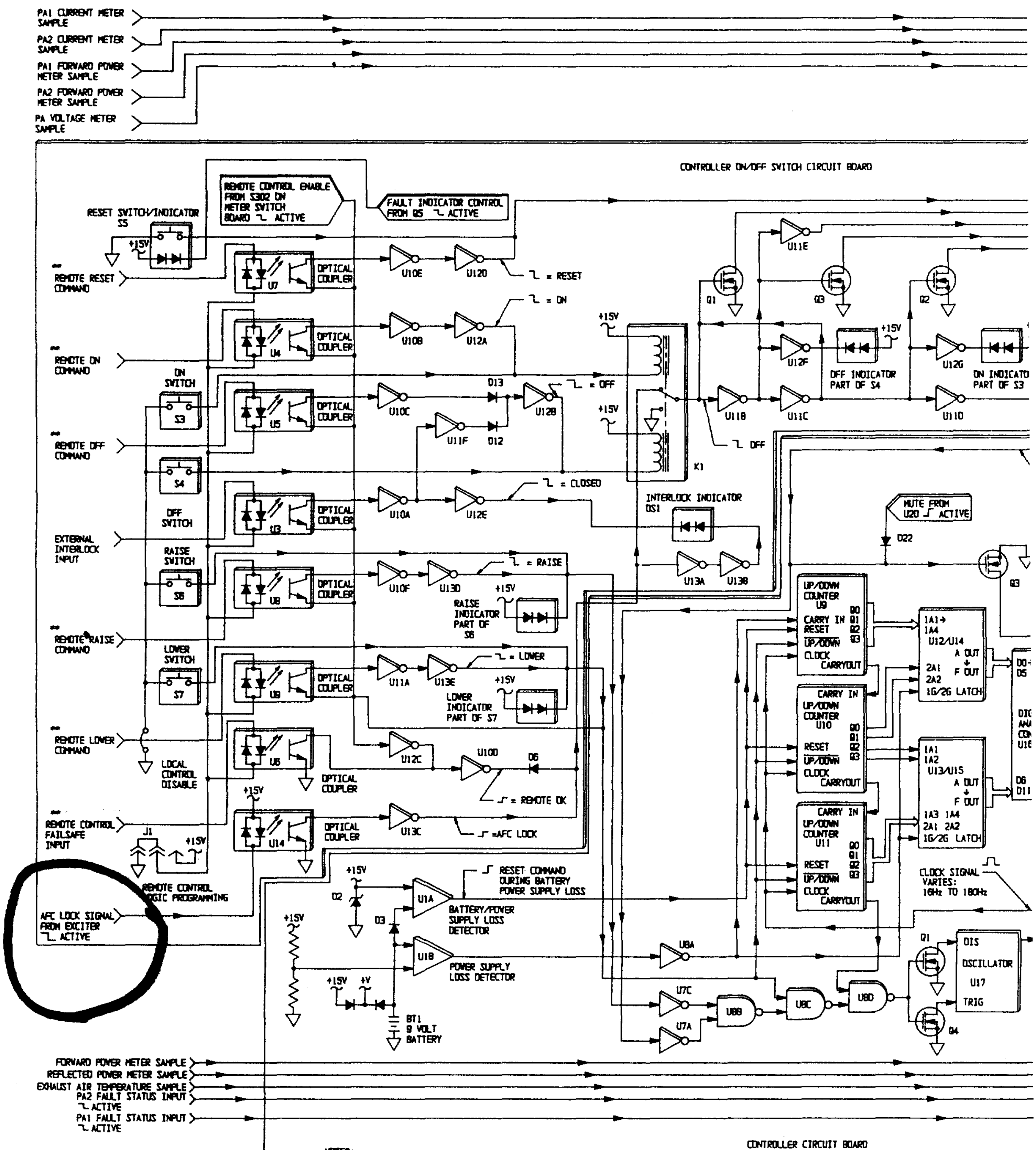
BROADCAST ELECTRONICS, INC.

Appendix A

Typical Automatic Frequency Control Circuit
with
Transmitter Interlock



NOTES:

* +4VDC REMOTE METER SAMPLE WITH R13 INSTALLED

  +2VDC REMOTE METER SAMPLE WITH R13 REMOVED

** POSITIVE LOGIC: ⎍ ACTIVE

NEGATIVE LOGIC: ⊔ ACTIVE

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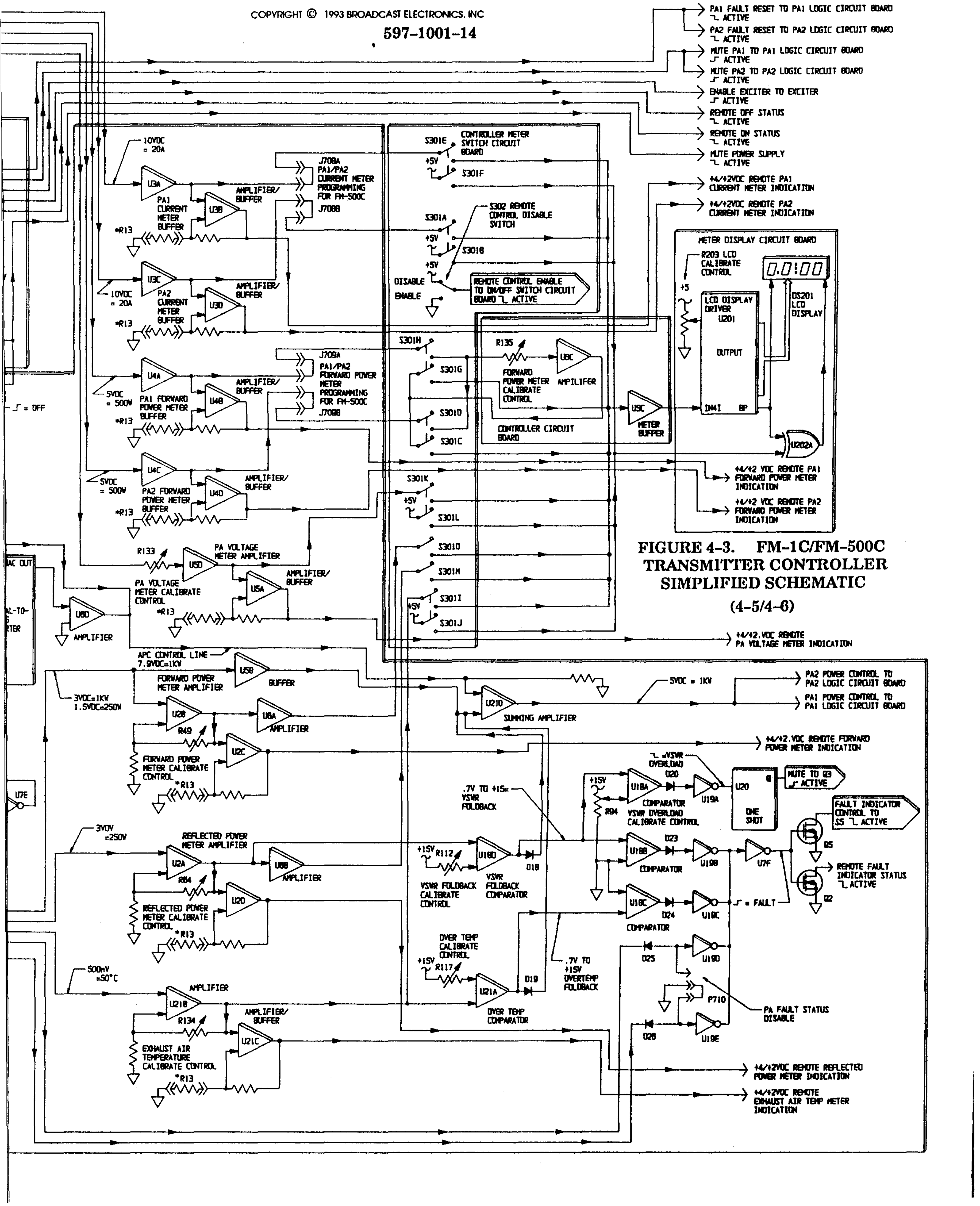

FIGURE 4-3. FM-1C/FM-500C TRANSMITTER CONTROLLER SIMPLIFIED SCHEMATIC

(4-5/4-6)

TABLE 3-1. FM-1C CONTROLS AND INDICATORS
(Sheet 2 of 4)

INDEX NO.	NOMENCLATURE	FUNCTION
6	**POWER ▼** Switch/Indicator	**SWITCH:** Instructs the system controller to lower the transmitter output power. **INDICATOR:** Illuminates to indicate the **POWER ▼** switch is selected.
7	**RESET** Switch/Indicator	**SWITCH:** Clears the transmitter fault circuitry if: 1) the switch is depressed and 2) if the fault condition is removed. **INDICATOR:** Illuminates to indicate: 1) an RF power module has been removed from the chassis, 2) a power amplifier fault, 3) a high temperature condition, or 4) a high reflected power condition.
8	**INTERLOCK** Switch/Indicator	**SWITCH:** No Operation. **INDICATOR:** Illuminates to indicate: 1) the external interlock is closed, 2) the exciter AFC is locked, and 3) the remote control fail-safe input is closed if remote control operation is enabled. Extinguishes to indicate an open external interlock, the exciter AFC is unlocked, or an open remote control fail-safe input if remote control operation is enabled.
9	**REMOTE CONTROL ENABLE/DISABLE** Switch	Controls the transmitter remote control operations. When the switch is operated to **ENABLE**, remote control operation is enabled. When the switch is operated to **DISABLE**, remote control operation is disabled.
10	**LOCAL CONTROL ENABLE/DISABLE** Switch (Optional)	Controls the transmitter local control operations. When the switch is operated to **ENABLE**, the transmitter front-panel controls will be enabled. When the switch is operated to **DISABLE**, the transmitter front-panel controls will be disabled.
11	**PA2 CURRENT** Switch/Indicator	**SWITCH:** Configures the **MULTIMETER** to display power amplifier module 2 current. **INDICATOR:** A yellow display indicates the **MULTIMETER** is configured to present power amplifier module 2 current.
12	**PA2 FWD POWER** Switch/Indicator	**SWITCH:** Configures the **MULTIMETER** to display power amplifier module 2 forward power. **INDICATOR:** A yellow display indicates the **MULTIMETER** is configured to present power amplifier module 2 forward power.

5–154. **Power Amplifier Module Exchange Program.** If a power amplifier module is determined to be defective, Broadcast Electronics has established a power amplifier module exchange program. The program allows the customer to: 1) exchange a defective module for a reconditioned module or 2) obtain a module on loan during the repair of the defective module. Terms of the program are available from the Broadcast Electronics Customer Service Department.

5–155. **TRANSMITTER TROUBLESHOOTING PROCEDURES.** Table 5–1 presents troubleshooting information for the FM–1C/FM–500C transmitters. Refer to Table 5–1 to isolate the problem to a specific assembly. Once the trouble is isolated, refer to the theory of operation and schematic diagrams to assist in problem resolution.

5–156. **TRANSMITTER COMPONENT LOCATIONS.** Figure 5–3 presents the transmitter component locations. Refer to Figure 5–3 as required during the troubleshooting procedures to locate components within the transmitter.

TABLE 5–1. FM–1C/FM–500C TROUBLESHOOTING (Sheet 1 of 7)

SYMPTOM	CIRCUITRY TO CHECK
NO OUTPUT POWER INTERLOCK INDICATOR EXTINGUISHED MODULE STATUS INDICATORS ILLUMINATE YELLOW EXCITER LOCK INDICATOR EXTINGUISHED	1. Exciter AFC is unlocked. Refer to the FX–50 exciter manual and troubleshoot the exciter.
NO OUTPUT POWER MODULE STATUS INDICATORS ILLUMINATE YELLOW INTERLOCK INDICATOR EXTINGUISHED	1. Operate the remote control switch to disable. A. If the interlock indicator is extinguished, check the external interlock. B. If the interlock indicator illuminates, check the remote control unit.
FM–1C LOW OUTPUT POWER MODULE STATUS INDICATORS ILLUMINATE YELLOW	1. Check the exciter forward power. The forward power must be 40 W. 2. If the exciter forward power is low, refer to the FX–50 exciter manual and troubleshoot the exciter. 3. If the correct exciter forward power is present, depress the PWR SUPPLY VDC switch. The voltage must be equal to the normal operating voltage. 4. If the PA voltage is normal, bypass the low–pass filter and connect the transmitter output to a test load. 1. If the MODULE STATUS indicators remain yellow, defective combiner or both RF amplifier modules. 2. If the MODULE STATUS indicators illuminate green, defective low–pass filter. 5. If the PA voltage is low, increase the PA voltage until the MODULE STATUS indicators illuminate green.

WARNING: DISCONNECT POWER PRIOR TO SERVICING

SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. This section provides general information and specifications relative to the operation of the automatic frequency control/phase-locked-loop (AFC/PLL) circuit board.

1-3. DESCRIPTION.

1-4. The AFC/PLL circuit board: 1) synthesizes and maintains the desired carrier frequency to a high degree of precision, and 2) processes the audio for modulation.

1-5. A sample of the modulated oscillator output frequency is compared to a precision reference frequency in a comparator circuit which generates a correction voltage. This correction voltage is applied to the modulated oscillator to maintain the stability of the carrier frequency. If the carrier is off frequency (as when power is applied), the AFC/PLL circuitry will mute the RF output until the carrier is locked in-phase with the reference frequency. A dual speed PLL filter ensures rapid stabilization of the carrier frequency.

1-6. In addition, the AFC/PLL circuit board accepts, sums, and precorrects audio input signals to provide a linear response when applied to the modulated oscillator.

1-7. ELECTRICAL CHARACTERISTICS.

1-8. Refer to Table 1-1 for electrical characteristics relative to the AFC/PLL circuit board.

SECTION III

THEORY OF OPERATION

3-1. INTRODUCTION.

3-2. This section presents the theory of operation for the exciter AFC/PLL circuit board.

3-3. FUNCTIONAL DESCRIPTION.

3-4. The AFC/PLL circuit board contains nine circuits. Figure 3-1 presents a simplified schematic of the AFC/PLL circuit board. Refer to Figure 3-1 as required for a description of the following circuits.

A. Reference Divider Circuit
B. Reference Oscillator Activity Monitor
C. RF Sample Divider Circuit
D. Comparator Circuit
E. Loop Filter Control Circuit
F. VCO Activity Monitor
G. Audio Processing Circuits
H. Pre-modulation Control Circuit
I. Voltage Regulator Circuits

3-5. REFERENCE DIVIDER CIRCUIT.

3-6. This divider circuit provides an accurate and stable reference frequency for input to a comparator circuit. A 10 MHz signal from crystal oscillator Y1 is input to divide-by-five counter U1B to produce 2 MHz. These two frequencies are available at TP1 through programmable jumper J3.

3-7. The 2 MHz signal from U1B is input to divide-by-two counter U1A to produce 1 MHz. Logic circuits U2, U3, and U4A further divide the 1 MHz signal by 250 to provide 4 kHz to one shot U5. The 4 kHz signal at the $\overline{QA}$ output of U5 is applied to programmable frequency synthesizer and comparator U9.

3-8. REFERENCE OSCILLATOR ACTIVITY MONITOR.

3-9. This circuit provides a visual indication of the reference divider circuit output. When the 4 kHz signal is present, the QB output of U5 will go HIGH which biases LED driver transistor Q1 ON to illuminate indicator DS2.

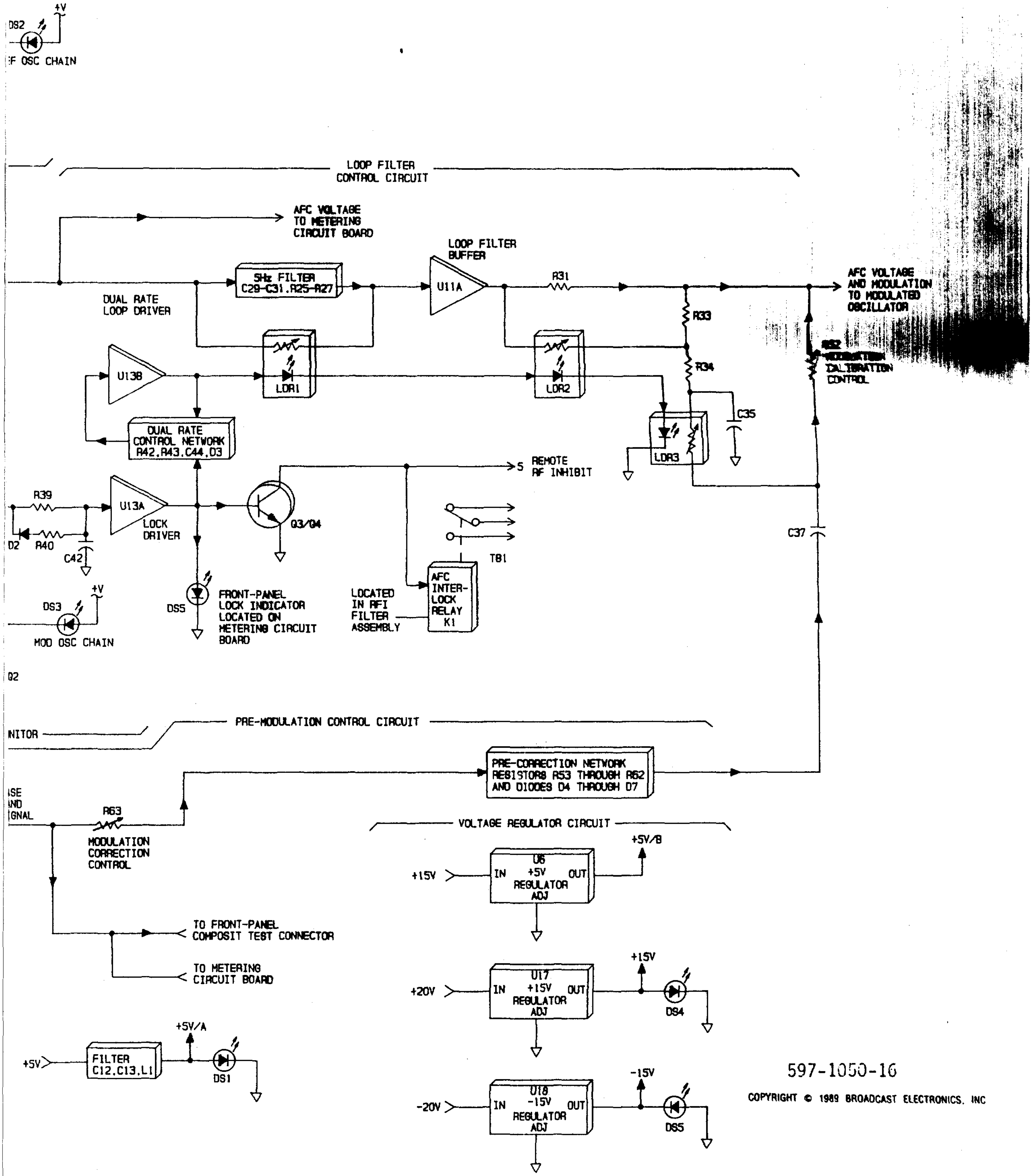

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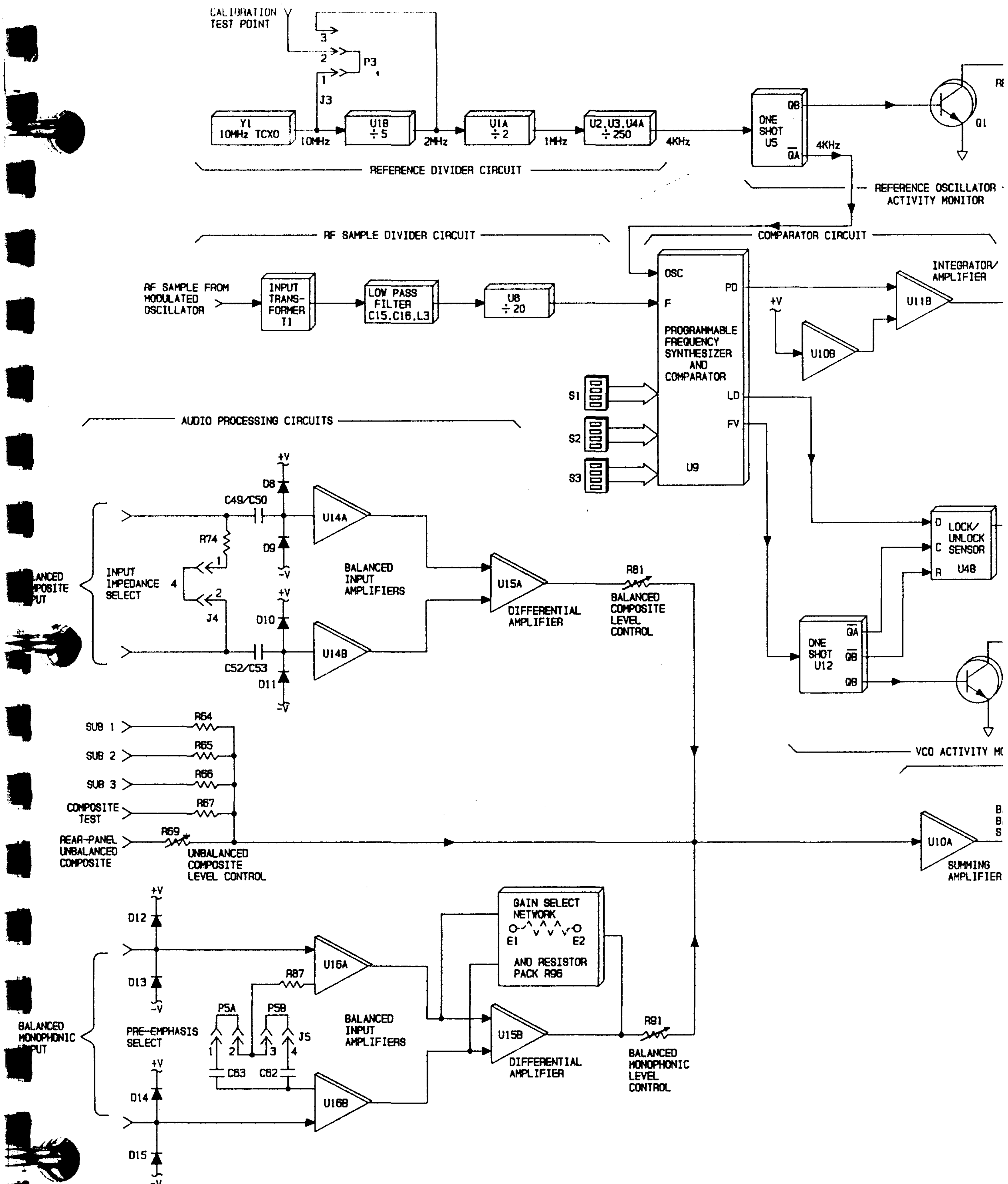
FIGURE 3-1.
AFC/PLL CIRCUIT BOARD SIMPLIFIED SCHEMATIC



CALIBRATION TEST POINT
P3
J3
Y1 10MHz TCXO
10MHz
U1B ÷ 5
2MHz
U1A ÷ 2
1MHz
U2,U3,U4A ÷ 250
4KHz
ONE SHOT U5
QB
QA
Q1
REFERENCE DIVIDER CIRCUIT
REFERENCE OSCILLATOR ACTIVITY MONITOR
RF SAMPLE DIVIDER CIRCUIT
COMPARATOR CIRCUIT
RF SAMPLE FROM MODULATED OSCILLATOR
INPUT TRANS-FORMER T1
LOW PASS FILTER C15,C16,L3
U8 ÷ 20
OSC
F
PD
LD
FV
PROGRAMMABLE FREQUENCY SYNTHESIZER AND COMPARATOR
U9
S1
S2
S3
INTEGRATOR/ AMPLIFIER
U11B
U10B
+V
LOCK/ UNLOCK SENSOR
U4B
D
C
R
ONE SHOT U12
VCO ACTIVITY MO
AUDIO PROCESSING CIRCUITS
C49/C50
D8
D9
R74
U14A
INPUT IMPEDANCE SELECT
J4
D10
D11
C52/C53
U14B
BALANCED INPUT AMPLIFIERS
U15A
DIFFERENTIAL AMPLIFIER
R81
BALANCED COMPOSITE LEVEL CONTROL
SUB 1
SUB 2
SUB 3
COMPOSITE TEST
REAR-PANEL UNBALANCED COMPOSITE
R64
R65
R66
R67
R69
UNBALANCED COMPOSITE LEVEL CONTROL
U10A
SUMMING AMPLIFIER
GAIN SELECT NETWORK
E1
E2
AND RESISTOR PACK R96
D12
D13
D14
D15
U16A
U16B
R87
P5A
P5B
J5
PRE-EMPHASIS SELECT
C63
C62
BALANCED MONOPHONIC INPUT
BALANCED INPUT AMPLIFIERS
U15B
DIFFERENTIAL AMPLIFIER
R91
BALANCED MONOPHONIC LEVEL CONTROL

3-10. RF SAMPLE DIVIDER CIRCUIT.

3-11. This divider circuit provides an RF sample frequency for input to the comparator circuit. An RF sample from the modulated oscillator is input to transformer T1 to reduce ground loop interference. The output of T1 is coupled to a low-pass filter consisting of capacitors C15, C16, and inductor L3 which eliminates any harmonics.

3-12. The sinusoidal output signal from the low-pass filter is applied to the input of counter U8. U8 will divide the sample frequency by 20 and output a digital signal to U9.

3-13. COMPARATOR CIRCUIT.

3-14. This circuit compares the signals from both the reference divider and RF sample divider circuits and generates an error signal when a difference exists. Logic circuit U9 is a programmable frequency synthesizer and comparator which will internally divide the 4 kHz signal at the OSC input to provide a frequency of 500 Hz.

3-15. When binary switches S1, S2, and S3 are preset for the appropriate carrier frequency, U9 will divide the RF sample signal at the F input to provide 500 Hz at the FV output which is applied to one shot U12. If an error exists, output FV will vary above or below 500 Hz. This signal and the 500 Hz from the reference division are internally compared for phase and frequency variations.

3-16. When the carrier frequency and reference frequency are equal and in phase, the PD output of U9 will be steady state at approximately +2.5 volts. If the carrier leads or is greater than the reference frequency, the output will pulse LOW. If the carrier lags or is less than the reference frequency, the output will pulse HIGH. These output pulses will vary in width directly in proportion to the degree of phase error. The pulses are applied to U11B.

3-17. Normally, the LD output of U9 will be a logic HIGH for a locked condition. If an unlocked condition exists, the output will pulse LOW. This output is applied to the D input of lock/unlock sensor U4B. With the signal from the FV output of U9, the $\overline{QA}$ output of one shot U12 will provide a clock pulse to U4B which leads or lags the signal at the D input depending on the phase error direction.

3-18. LOOP FILTER CONTROL CIRCUIT.

3-19. The loop filter control circuit increases/decreases the voltage controlled oscillator (VCO) center frequency to maintain accuracy. U10B biases integrator/amplifier U11B at 2.5V to provide a voltage gain of 11 for any differential voltage within the range of the bias. The output of U11B is applied to the metering circuit board for display.

3-20. ACTIVE FILTER. The output of U11B is also applied to an active third-order 5 Hz low-pass filter consisting of capacitors C29 through C31, resistors R25 through R27, and loop filter buffer U11A. The filter removes the reference frequency component to provide a dc automatic frequency control (AFC) voltage to the modulated oscillator through resistor R31.

3-21. LOCK DRIVER. The output of lock/unlock sensor U4B normally applies a HIGH through resistor R39 to lock driver U13A for a locked-loop condition. U13A is activated by a slow charge/rapid discharge circuit consisting of resistors R39, R40, diode D2, and capacitor C42.

3-22. As long as the output of U4B is HIGH, the potential on C42 will maintain U13A output HIGH. This HIGH will: 1) illuminate front-panel LOCK indicator DS5, 2) bias transistor switch Q3/Q4 ON to remove the RF inhibit from the rear-panel terminal strip, and 3) enable the AFC relay.

3-23. If an unlock condition exists, the output of U4B will go LOW which rapidly discharges C42 through D2 and R40 and applies a LOW to U13A. When this occurs, the output of U13A will go LOW to extinguish the lock indicator, disable the AFC relay, inhibit the RF, and activate a dual rate loop driver.

3-24. DUAL RATE LOOP DRIVER. The LOW output from U13A is routed to a dual rate control network consisting of R42, R43, C44, and D3. This circuit is identical in operation to the slow charge/rapid discharge circuit previously described. The circuit forces the output of U13B HIGH which enables light dependent resistors LDR1, LDR2, and LDR3 in the active filter circuit to increase loop lock response.

3-25. LOOP LOCK RESPONSE. Increased loop lock response is accomplished by LDR1, LDR2, and LDR3. When enabled during an unlocked condition, LDR1 will shunt the 5 Hz low-pass filter and route the output from U11B directly to U11A. LDR2 will shunt resistor R31 to rapidly charge capacitor C35 through resistor R34. Modulation coupling capacitor C37 will be rapidly charged through LDR3.

3-26. LOCK UP. When the operating frequency and phase output of the modulated oscillator are sufficiently adjusted by the AFC control voltage, the output of U4B will return HIGH which changes the output state of U13A and U13B. The duration between the unlock and lock conditions is less than 5 seconds.

3-27. VCO ACTIVITY MONITOR.

3-28. This circuit indirectly provides a visual indication of output from the RF sample divider circuit via the FV output of U9. When the 500 Hz signal is present, the QB output of U12 will go HIGH which biases LED driver transistor Q2 ON to illuminate indicator DS3. If any component within the RF sample divider circuit or modulated oscillator circuit fails, indicator DS3 will extinguish and the $\overline{QB}$ output of U12 will issue a reset pulse to U4B which inhibits the RF.

BROADCAST ELECTRONICS, INC.

Appendix B

Typical Automatic Power Control Circuit

SECTION I
APC THEORY OF OPERATION

1–1. INTRODUCTION.

1–2. The following text provides theory of operation with supporting diagrams for the FM–1B/FM–1.5B transmitter automatic power control unit.

1–3. FUNCTIONAL DESCRIPTION.

1–4. Two levels of discussion are provided. A general discussion of the automatic power control unit operation at block diagram level is followed by a detailed discussion of circuit operation.

1–5. GENERAL DESCRIPTION.

1–6. The automatic power control unit (APC) measures several transmitter parameters and allows both manual and automatic control of RF power output (refer to Figure 1–1). Additional features include switched operation to a power level which has been predetermined (preset power), automatic power reduction in event of an output VSWR (VSWR foldback), and automatic reduction of power to minimum at plate–off so that when power is reapplied, full RF output will not suddenly be established, but will slowly increase from minimum (soft start). The unit also contains a front–panel receptacle for AM noise measurements.

1–7. **OPERATION.** Manual power control can be selected by switching the APC off. In the manual mode, the **RAISE** and **LOWER** switch/indicators directly control the dc potential which varies the exciter RF output. The **RAISE** and **LOWER** switch/indicators indicate whether transmitter RF output power is being raised or lowered.

1–8. In the automatic mode, the **RAISE** and **LOWER** switch/indicators control a reference voltage stored as an eight–bit word in a digital memory. A nine–volt battery maintains this memory after a power failure so that restoration to operation will proceed automatically after power is reapplied. Battery power consumption of 0.8 microamperes results in a battery life of approximately two years (the shelf life of an alkaline battery).

1–9. The APC uses a modulated pulse train scheme to vary the RF output. When large excursions of RF power are required, a more rapid pulse train is employed. Fine adjustments of RF output utilize a slower pulse train and therefore slower correction. This feature, combined with an analog deadband in the circuitry, eliminates hunting in this loop.

1–10. Three circuitboard mounted LED indicators provide information concerning operation of the APC for maintenance personnel. Each indicator will illuminate to signify its respective function or parameter is active or out–of–tolerance.

1–11. The APC houses the circuitry which rectifies and calibrates the PA directional coupler forward and reflected power signals. These signals serve as APC control inputs and are applied to the **OUTPUT POWER** meter for measurement. These parameters allow automatic control of the exciter RF output as part of a closed loop. If excessive PA reflected power is measured, the "raise power" function will be inhibited to prevent an overload condition. The absence of plate voltage will inhibit the raise function and signal the circuit to adjust the exciter RF output to minimum. Excessive transmitter RF output or a high PA reflection will first inhibit the raise function. If the condition exceeds built–in limits, the circuit will initiate a sequence which lowers power proportionately in response to the condition.

1–12. **VSWR Foldback.** In the automatic mode, PA power will be automatically reduced if PA reflected power becomes excessive enough to overload the transmitter. As the condition which caused the high VSWR returns to normal, RF power will be proportionally raised until full output is restored. A similar circuit for PA forward power will reduce power if the output is excessive. The balance of these two circuits stabilizes the transmitter output at a specific level.

1–13. **Soft Start.** In the automatic mode, a circuit monitors plate voltage and reduces the exciter RF output to minimum upon the absence of plate voltage. When the plate supply is energized, as during power–on, the circuit will gradually increase the exciter output until the "stored" power level is achieved. This circuit prevents inadvertent cycling of the VSWR overload at turn–on if the load is not optimal, such as during an ice storm.

1–14. **Preset Power.** The preset power function provides a simple means to switch the transmitter output power to a predetermined level other than the rated output power. This feature can be conveniently activated with a generator for emergency operation at a lower power level.

1–15. **Power Supply.** The APC power supply consists of two +15 volt regulated sources, a +12 volt regulated source, and a +9.9 volt source established by a zener diode. Each +15 volt supply is fused with a one–ampere fuse. The entire supply is overload protected by two half–ampere fuses in the primary circuit.

1–16. **DETAILED DESCRIPTION.**

1–17. The APC unit circuitry is implemented on three circuit boards with certain additional components (such as the power transformer) mounted to the chassis.

A. The front panel circuit board contains the switch/indicators and some resistors which calibrate the OUTPUT POWER METER circuitry.

B. The rear panel circuit board primarily contains interface circuitry. It 1) contains the forward and reflected power rectifier circuitry, 2) the PI section low–pass filters which provide RFI filtering for all ac, dc and control inputs and 3) the power supplies which operate the unit.

C. The main circuit board contains all the circuitry required to implement the APC analog and digital control functions.

D. The digital–to–analog converter circuit board contains circuitry which converts the APC digital output into an analog voltage as required to adjust the exciter output level.

1–18. **POWER SUPPLY.** The APC power supply operates from an input of 230 volts ac at a maximum of 1/2 ampere (see Figure 1–2). AC power is input through RFI filter FL1 which provides 55 dB of attenuation to frequencies of 10 MHz and above. A conservatively rated power transformer allows operation from both 50 and 60 Hz. Fuses F1 and F2 provide overload protection for the primary circuit and metal–oxide varistor MOV1 provides suppression of transient voltage surges.

1–19. The secondary of transformer T1 is full–wave bridge rectified by diodes D6, D7, D8, and D9 into a +28 volt source and filtered by C34. This potential is regulated into four seperate sources.

1–20. **Positive Fifteen Volt Source A.** The input potential is regulated into a 15 volt supply by U1. Capacitor C35 prevents regulator oscillation and C46 improves the response of the regulator. The output voltage is established by the value of resistors R24 and R25. The output of this source operates all APC logic.

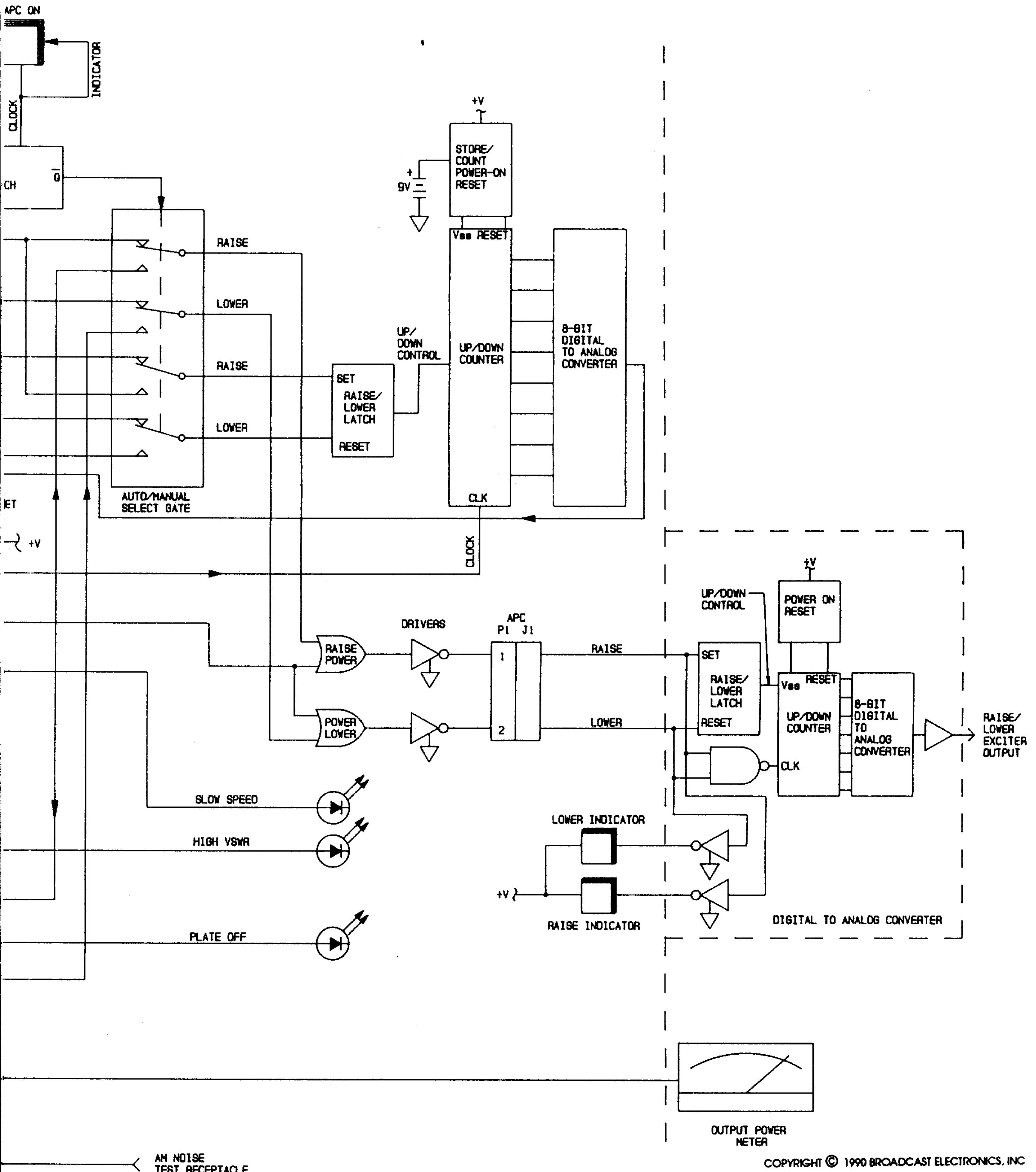


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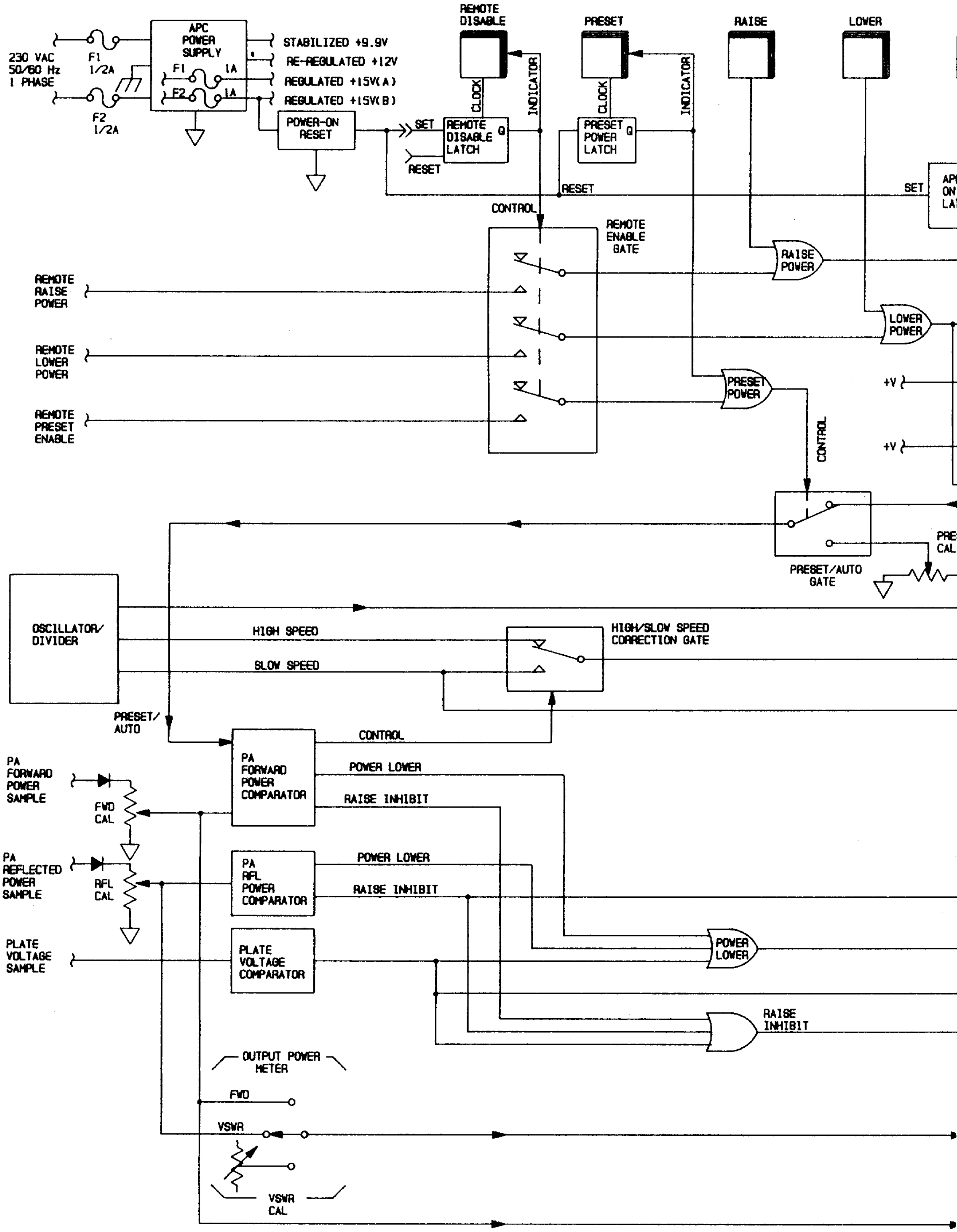
FIGURE 1-1. APC BLOCK DIAGRAM



230 VAC
50/60 Hz
1 PHASE
F1
1/2A
F2
1/2A
APC
POWER
SUPPLY
F1
1A
F2
1A
STABILIZED +9.9V
RE-REGULATED +12V
REGULATED +15V(A)
REGULATED +15V(B)
POWER-ON
RESET
REMOTE
DISABLE
PRESET
RAISE
LOWER
CLOCK
INDICATOR
SET
REMOTE
DISABLE
LATCH
Q
RESET
PRESET
POWER
LATCH
SET
CONTROL
REMOTE
ENABLE
GATE
RAISE
POWER
LOWER
POWER
PRESET
POWER
REMOTE
RAISE
POWER
REMOTE
LOWER
POWER
REMOTE
PRESET
ENABLE
+V
PRESET/AUTO
GATE
OSCILLATOR/
DIVIDER
HIGH SPEED
SLOW SPEED
HIGH/SLOW SPEED
CORRECTION GATE
PRESET/
AUTO
PA
FORWARD
POWER
COMPARATOR
POWER LOWER
RAISE INHIBIT
PA
FORWARD
POWER
SAMPLE
FWD
CAL
PA
REFLECTED
POWER
SAMPLE
RFL
CAL
PA
RFL
POWER
COMPARATOR
PLATE
VOLTAGE
SAMPLE
PLATE
VOLTAGE
COMPARATOR
POWER
LOWER
RAISE
INHIBIT
OUTPUT POWER
METER
FWD
VSWR
VSWR
CAL